

Operation Of Wet Scrubbers

Introduction

Wet scrubbers are air pollution control devices that use liquid to remove particles or gases from exhaust streams. The particles are captured by and incorporated into liquid droplets. These droplets must then be separated from the exhaust stream. (Occasionally, wet scrubbers are used to remove gases. The gases are dissolved in or absorbed by the liquid.)

Wet scrubbers remove particles or gases from exhaust streams.

The four major categories of particulate matter wet scrubbers include: spray tower scrubbers; packed bed, moving bed, and tray-type scrubbers; mechanically aided scrubbers; and gas-atomized scrubbers. The following sections describe the general configuration of each of these scrubbers, common components of each scrubber system, and important operating parameters of each.

Spray Tower Scrubbers

The spray tower scrubber is the simplest type of scrubber used for removing particulate pollutants. It is a vertical tower with one or more sets of spray nozzles. The gas stream can pass straight up the tower, as shown in Figure 6-1, or the unit can be designed with a cyclonic flow section near the bottom, as shown in Figure 6-2.

Spray tower scrubbers are the simplest type of scrubber.

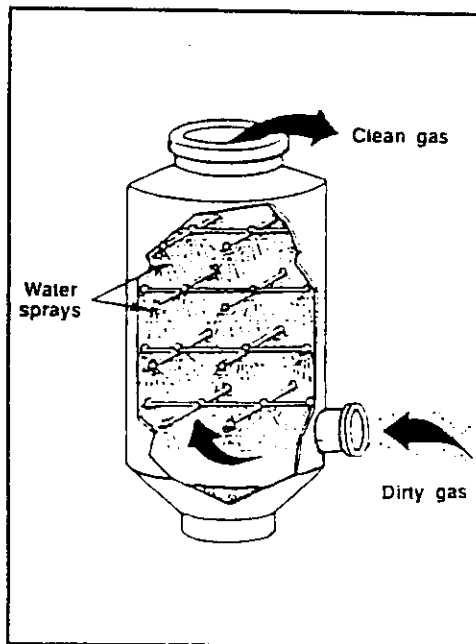


Figure 6-1. Spray Tower

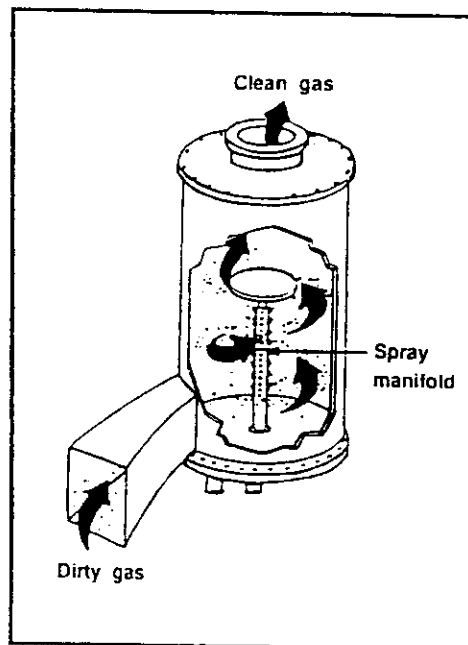


Figure 6-2. Cyclone Spray Tower

Typical gas stream velocities range from 2 to 4 ft/s. The static pressure drop across the unit is generally quite low. **Demisters** are used in the top of the scrubber vessel to reduce the quantity of water droplets emitted from the scrubber. The two most common types of demisters for this type of scrubber are **chevron blade demisters** and **mesh pad demisters**. Figures 6-3 and 6-4 illustrate a chevron blade demister and a mesh pad demister, respectively.

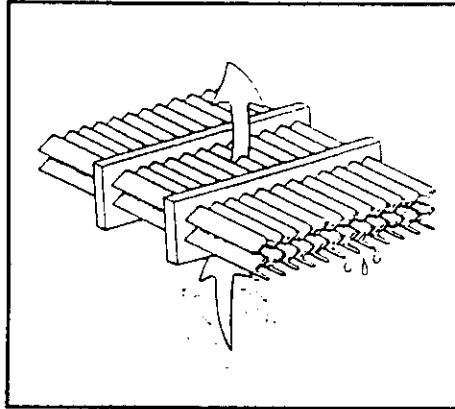


Figure 6-3. Chevron Blade Demister

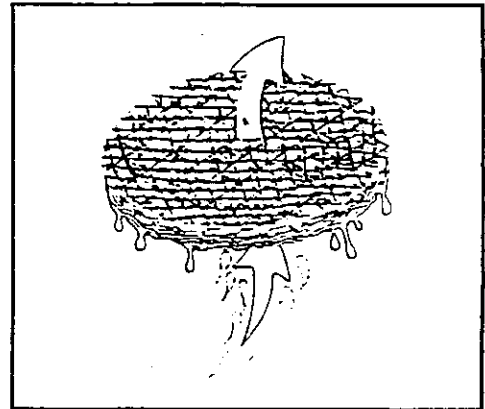


Figure 6-4. Mesh Pad Demister

Spray tower scrubbers are difficult to evaluate, because they often lack instrumentation and some parts of the scrubber are difficult to access.

Spray tower scrubbers are often difficult to evaluate because demister and spray nozzle header areas are not easily accessible. Also, some systems might not have inlet gas temperature recorders, liquor pH recorders, recirculation-liquor flow rate indicators, pump discharge pressure gauges, or nozzle discharge pressure gauges.

Particle size distribution is the most important performance factor for spray tower scrubbers.

Factors that govern performance of spray tower scrubbers are the type and orientation of spray nozzles, the physical condition of the spray nozzles, the liquid-to-gas ratio, the solids content of the scrubbing liquor, and the particle size distribution. Particle size distribution is the most important factor because the spray tower scrubber is capable of only limited small-particle removal. Nozzle erosion and plugging can also be problems. The nozzle orifice increases in diameter as particles collected in the recirculating scrubbing liquid erode the nozzle opening. The size of the scrubbing liquid droplets grows larger as the nozzle opening erodes. This causes a decrease in the collection efficiency of the scrubber. Also, since nozzles are enclosed in the scrubber, their conformance to design specification is difficult to assess.

One of the most important operating parameters affecting the efficiency of a wet-dry-type dry scrubber system is the approach-to-saturation. This is simply the difference between the readings of the wet bulb and dry bulb temperature monitors at the point where the gas stream leaves the spray dryer vessel.

Packed Bed, Moving Bed, And Tray-Type Scrubbers

A variety of commercial designs are available for these types of scrubbers. The scrubbers are always vertical cylinders; however, the method of gas-liquid contact differs among the three designs.

Packed Bed Scrubbers

Figure 6-5 is a sketch of a countercurrent-flow packed bed scrubber. The gas stream enters from the bottom and passes upward through one or more beds of solid packing material. Spray nozzles distribute scrubber liquor over the top of the first bed, and the liquor passes downward over the surface of the packing. The packing maximizes the amount of surface area available for absorption of gases and vapors.

The primary function of packing is to maximize the amount of surface area available for absorption.

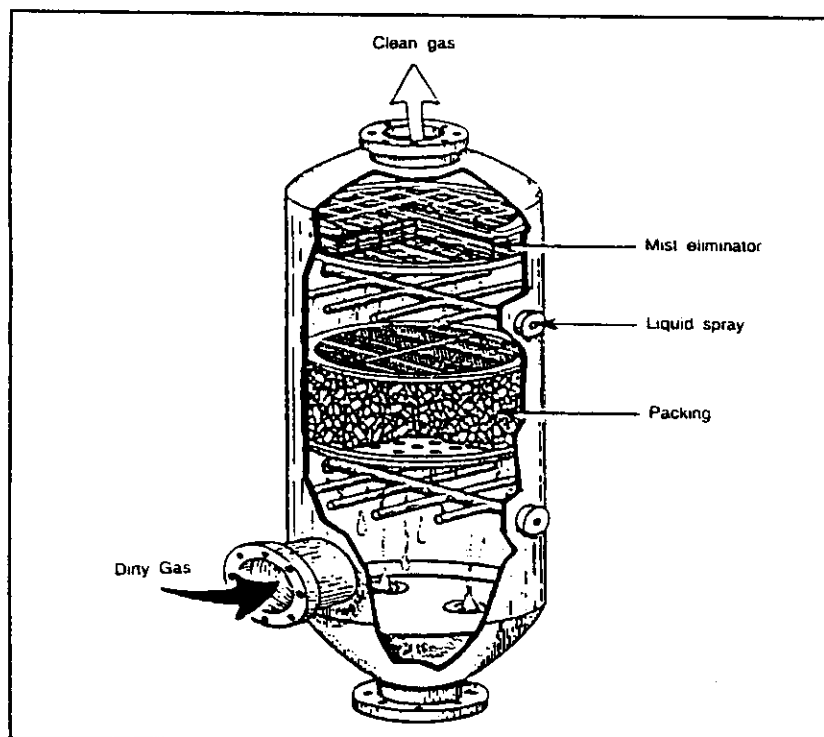


Figure 6-5. Countercurrent-Flow Packed Bed Scrubber

The packed bed (or packed tower) scrubber is capable of only limited particulate matter control, because the gas stream passes upward through the open areas of the packing at relatively low velocities. Also, the low velocities of the liquor passing down through the packing result in inefficient removal of deposited solids. Therefore, this type of scrubber is not appropriate for sources with high solids loadings in the gas stream. Despite these limitations, these scrubbers have been successfully used to remove particulate matter from some sources (e.g., smelter dissolving tanks, kraft pulp mills, and adipic acid plants).

Lesson 6

The most important operating variables for packed bed scrubbers are gas velocity and degree of channeling.

The most important operating variables for packed bed scrubbers are gas velocity through the bed and degree of gas-stream channeling as the gas flows through the packing.

Moving Bed Scrubbers

As in a packed bed scrubber, the gas stream in a moving bed scrubber (Figure 6-6) enters from the bottom and passes up the scrubber vessel in a flow that is counter to the liquor. (It should be noted that most commercial units have several beds in series rather than the single stage bed shown in Figure 6-6.) The spray nozzles at the top of the unit are intended to provide sufficient gas-liquid distribution. The beds are partially filled with hollow spheres that move in a highly turbulent manner. The water droplets and water sheets that form because of ball motion provide targets for particulate matter to strike. This type of scrubber can also be used to remove gases.

Beds are partially filled with hollow spheres that move in a turbulent manner, creating water droplets for the particles to strike.

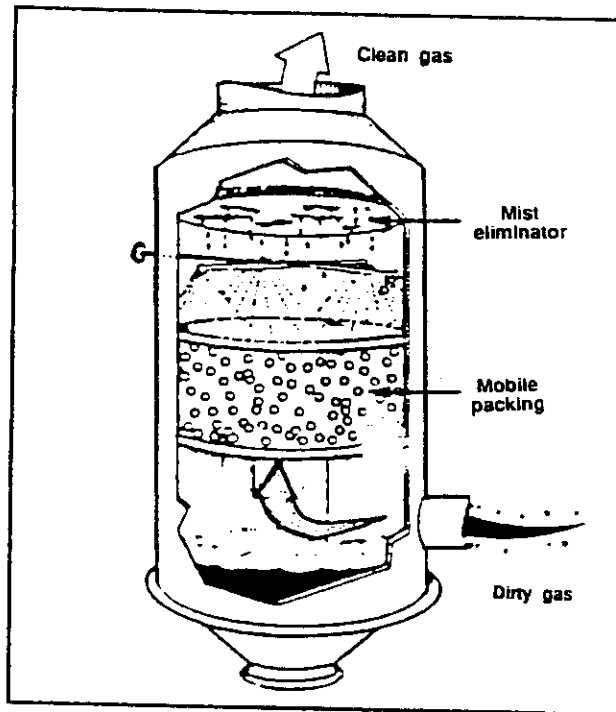


Figure 6-6. Moving Bed Scrubber

Moving beds are well suited for gas streams with high solids loadings or sticky particles.

Moving bed scrubbers are well suited for sources of sticky material or sources with high solids loadings because there are no restricted passages that can become plugged. Also, the turbulent action of the balls has a self-cleaning effect.

Key operating parameters of moving bed scrubbers include pressure drop, liquid-to-gas ratio, degree of channeling, and particle size distribution.

The most important factors controlling the performance of the moving bed scrubber include the pressure drop across the scrubber, the liquid-to-gas ratio, the degree of channeling through the bed, and the particle size distribution. Static pressure measurement ports are often installed before and after each bed. The number of instruments used depends on the size of the scrubber and the type of application.

Tray-Type Scrubbers

In tray-type scrubbers, the gas stream enters near the bottom of the scrubber vessel and passes upward through a series of horizontal trays containing holes. As the high-velocity gas stream flows through these holes and strikes a layer of water on the trays, atomized droplets of water are formed. The droplets provide a target for particulate matter to strike.

Tray-type scrubbers use trays to form atomized water droplets.

The scrubbing liquor enters the top and flows across each of the trays in sequence. **Downcomers** are used to move the liquor from one tray to the next. Figure 6-7 illustrates a tray-type scrubber with impingement trays (trays that enhance the process of particles adhering to water droplets), and Figure 6-8 illustrates other common tray designs.

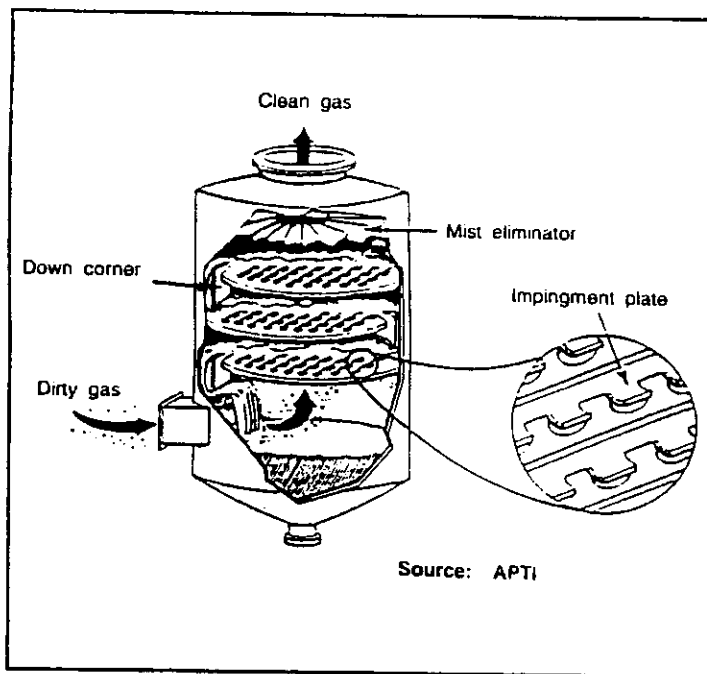


Figure 6-7. Tray-Type Scrubber

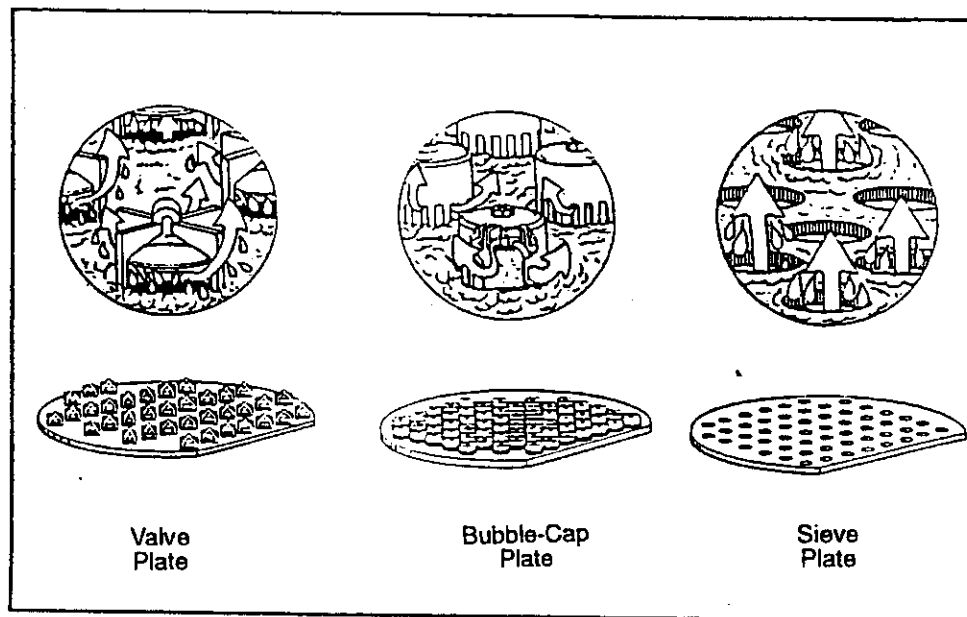


Figure 6-8. Other Tray Designs

Key operating parameters of tray-type scrubbers include liquor flow rate, degree of channeling, static pressure drop, suspended-solids content of the liquor, and surface tension of the liquor.

This basic scrubber design is moderately to highly efficient at removing particulate matter. Variables that control scrubber performance include the liquor flow rate, the degree of channeling, the static pressure drop, and the suspended-solids content of the liquor. Liquor pH is important because of possible corrosion. The surface tension of the liquor can affect the overall particulate matter removal efficiency, as well.

Mechanically Aided Scrubbers

The most common type of mechanically aided scrubber (also known as a wetted-fan scrubber) is similar to a fan equipped with water sprays (Figure 6-9). This unit can serve as a particulate matter control device and as a primary gas mover. As with any fan, there is a static pressure increase rather than a static pressure drop.

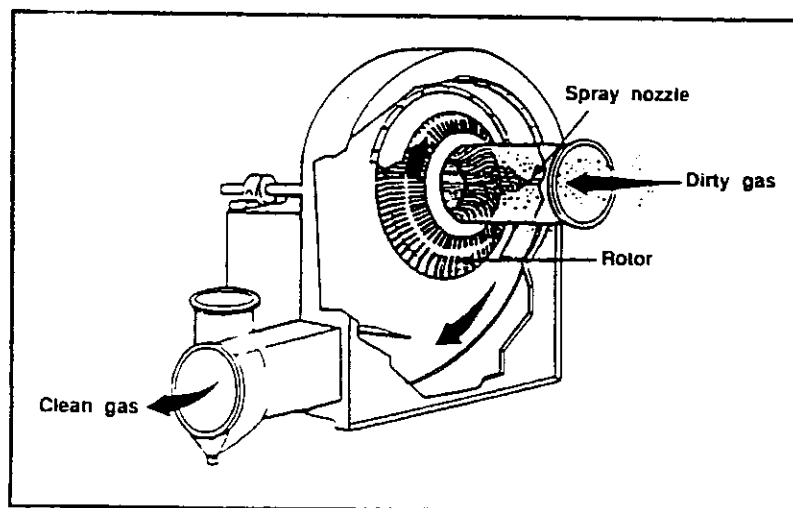


Figure 6-9. Mechanically Aided Scrubber

Most mechanically aided scrubbers are small units that use a mechanical force to increase particle activity. The mechanical force can be supplied by a fan or blower that helps to increase the particles' absorption in the water. The important scrubber operating variables include liquor flow rate and fan rotation speed. The suspended-solids content and the pH of the liquor are important because these determine the rate of erosion and corrosion of the fan blades.

Key operating parameters of mechanically aided scrubbers include liquor flow rate and fan rotation speed.

Gas-Atomized Scrubbers

This category of scrubbers includes all scrubbers that atomize the liquid stream by accelerating the gas stream in a restricted throat. The most common gas-atomized scrubbers include venturi, rod, and orifice scrubbers.

Venturi Scrubbers

In a typical venturi scrubber (Figure 6-10), the gas stream enters from the top and passes down the converging section to the throat. The liquor is injected near the throat entrance. The gas stream within the throat, moving at velocities between 15,000 and 40,000 ft/min, atomizes and accelerates the water droplets. The pollutant particles then strike (and are encapsulated within) these droplets.

Liquor is injected near the throat of a venturi scrubber, where the gas velocities are 15,000 to 40,000 ft/min.

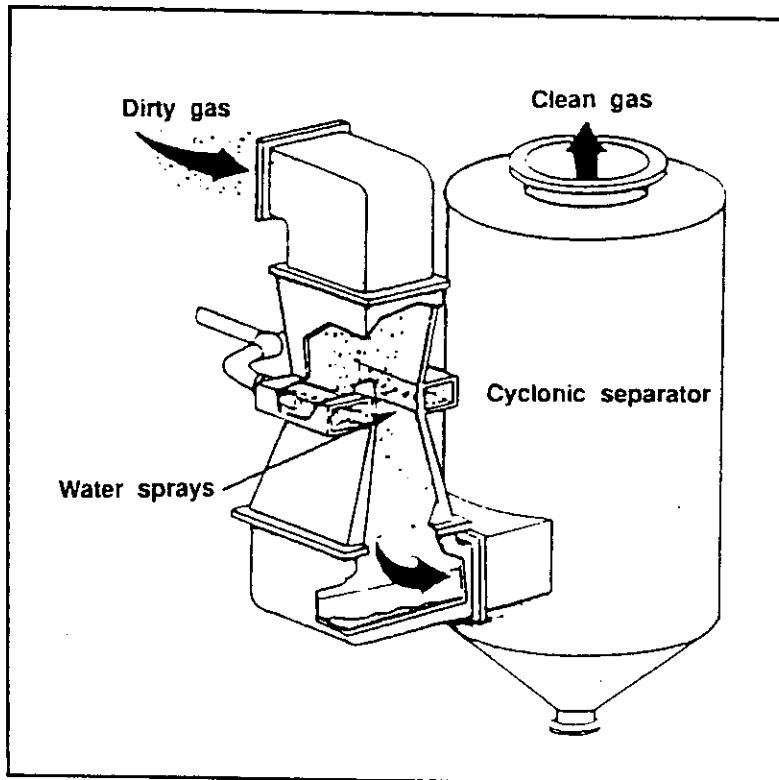


Figure 6-10. Venturi Scrubber

Lesson 6

Adjustable throat mechanisms are used to adjust gas velocity in some venturi scrubbers.

Some venturi designs include adjustable throat mechanisms so that gas velocity can be varied. Usually, one or two wear-resistant vanes are used for this purpose. The gas stream is slowed down in the diverging section of the venturi and is directed to a demister vessel that removes the entrained water droplets. Common demister designs include cyclonic and cylindrical chambers with either chevron blades or mesh pads.

Key parameters of venturi scrubbers include particle size distribution, static pressure drop, liquid-to-gas ratio, and surface tension.

The important operating variables for venturi scrubbers include the particle size distribution, the static pressure drop across the throat, and the liquid-to-gas ratio. Surface tension might also influence particle collection efficiency, especially for difficult-to-wet materials. The degree of gas-liquor mixing is an important factor because most particle collection occurs rapidly in the throat of the venturi, where the liquid and the pollutant particles are mixing under extremely turbulent conditions. The liquid is sheered into extremely fine droplets, which combine with particulate and gaseous pollutants and are collected. As these new liquid-particulate particles leave the venturi, they pass through a super-saturated lower pressure area, where they pick up more moisture through condensation.

The solids content and pH of the liquor influence the rate of erosion and corrosion of the shell and determine the useful life of the liquor nozzles near the throat. Vaporous pollutants arriving at the scrubber might not be effectively collected because the gas stream will pass through the throat before the material condenses to a particle and grows to a sufficient size to strike the droplets.

Rod and Orifice Scrubbers

Two other examples of gas-atomized scrubbers are shown in Figures 6-11 and 6-12. Figure 6-11 shows a single-stage, rod-type scrubber. The spaces between the rods are where the gas stream is accelerated and where the droplets are atomized. A set of spray nozzles above this deck serves to distribute the liquor evenly across the open area. In an orifice-type scrubber (Figure 6-12), the gas stream is forced through a narrow area underneath a partition. The turning gas stream entrains some of the liquor in a pool beneath the gas inlet. The atomized droplets serve as targets for the particles to strike.

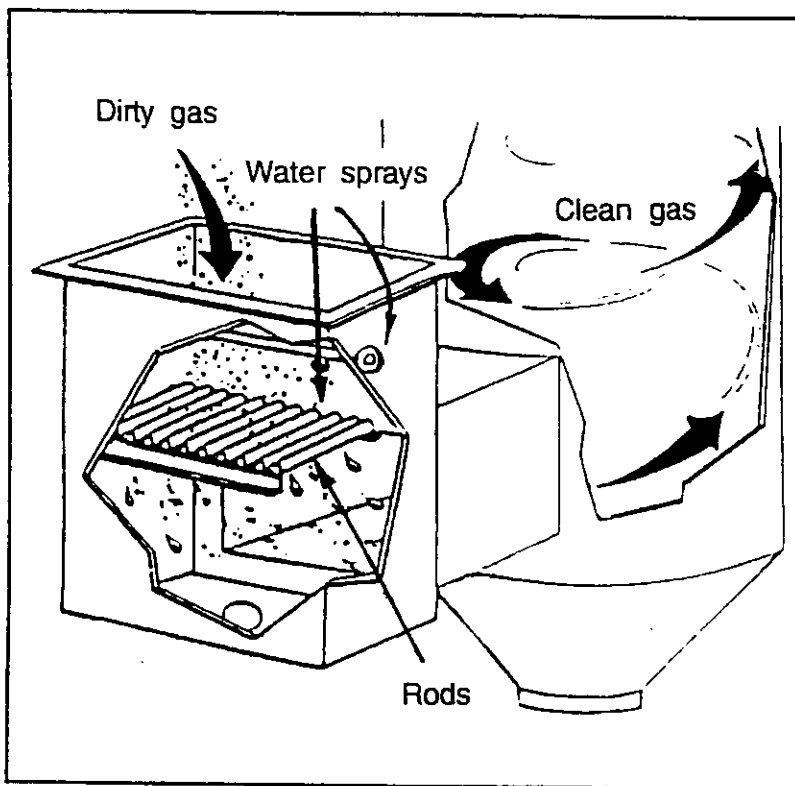


Figure 6-11. Rod-Type Scrubber

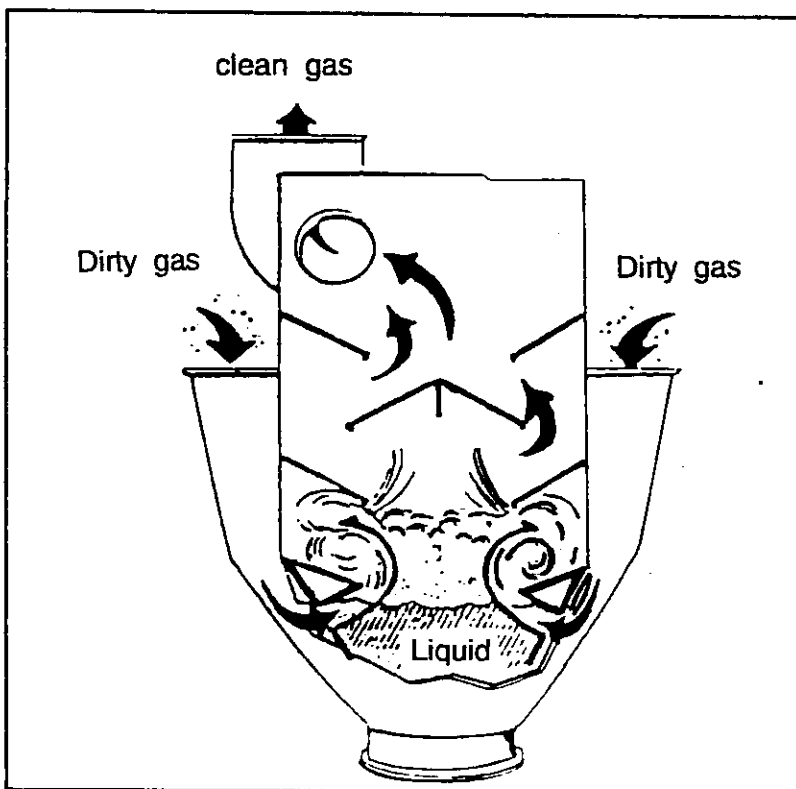


Figure 6-12. Orifice-Type Scrubber

The inspection procedures for rod- and orifice-type gas-atomized scrubbers are similar to those for a standard venturi scrubber. Their operating principles are also similar.

Typical Emission Points

The uncollected effluents or emissions from a wet scrubber are generally emitted through a stack or vent that is placed after the wet scrubber or is part of the scrubber system. Emissions can occur at corrosion and erosion points in the scrubber and associated ductwork.

Typical Inspection Areas

The major inspection areas for wet scrubber systems include:

- Stack or vent exit.
- Pressure gauges.
- Surrounding areas stained from droplet reentrainment.
- Physical condition of unit (corrosion and erosion).
- Liquor pH and turbidity (turbidity is related to the concentration of suspended particulate matter in the liquid).
- Liquor flow rate meter.
- Physical condition of demister.
- Spray nozzles (inspect only when out of service).
- Internal physical condition (when out of service).

Summary

Wet scrubbers are used to remove particulate pollutants or gaseous pollutants from exhaust streams. The predominate use of wet scrubbers, however, is in removing particulate pollutants. There are four major categories of wet scrubbers: spray tower scrubbers; packed bed, moving bed, and tray-type scrubbers; mechanically aided scrubbers; and gas-atomized scrubbers. The simplest of these scrubbers is the spray tower, in which particle size distribution is the most important factor in evaluating scrubber performance.

Packed bed scrubbers control particulate pollutants less efficiently, because the gas stream passes through at a relatively low velocity. Moving bed scrubbers are especially useful with sticky materials or other sources with high solids loadings. Tray-type scrubbers are moderately to highly effective in removing particulate pollutants. A mechanically aided scrubber is a common, small unit that serves as a particulate matter control device and as a gas mover. Venturi, rod, and orifice designs are gas-atomized scrubbers that atomize a liquid stream by accelerating the gas stream in a throat.

Review Exercises

1. Wet scrubbers are pollution control devices that use a liquid to remove ____ or ____ from an exhaust gas stream.
 - a. Atoms; molecules
 - b. Hydrogen; oxygen
 - c. Particles; gases
 - d. None of the above
2. True or false? The spray tower scrubber has only a limited ability to remove small particles.
3. Packing materials are used in wet scrubbers to:
 - a. Increase the weight of the system.
 - b. Provide a large surface area for absorption.
 - c. Provide high liquid flow rates.
 - d. Provide high gas flow rates.
4. Moving bed scrubbers are particularly well suited for controlling the following:
 - a. Gas streams with low solids loadings.
 - b. Gas streams with high solids loadings.
 - c. Gas streams with sticky material.
 - d. All of the above.
 - e. a and c only.
 - f. b and c only.
5. Is static pressure increase or static pressure drop the most important parameter in evaluating mechanically aided scrubbers?
6. In a venturi scrubber, the gas stream enters the_____, where it atomizes and accelerates water droplets.
 - a. Baffel
 - b. Throat
 - c. Portal
 - d. Demister
7. An important feature of an orifice scrubber is:
 - a. The size of the atomized droplets.
 - b. The venturi throat.
 - c. The pool of liquid.
 - d. All of the above.
8. True or false? The spaces between the rods in a rod scrubber are where the gas stream accelerates and where the droplets are atomized.

Answers

1. c. particles; gases
2. True
3. b. Provide a large surface area for absorption.
4. f. b and c only.
5. static pressure increase
6. b. Throat
7. d. All of the above.
8. True